Electro Industries / GaugeTech
The Leader in Metering Technology Solutions

EIG Loss Calculator Technical Description

The EIG Advantage
What is System Loss Compensation

- Adds or subtracts losses from meter registration
- Allows meter to be placed in most economical location
  - Meters often placed on low side of transformer
  - Significant savings in cost of VT and CT
  - Improves safety and lowers maintenance costs
Loss Compensation is calculated real-time in Nexus Meters using instantaneous voltage and current measurements.

- Demand, Energy, TOU, and Load Profile values are compensated.
- Compensation is based on the EEI Model from *The Handbook for Electricity Metering, 10th Edition and IMO MDP_STD_0005*. 

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The EEI and IMO Loss Model provides a PUC approved and commonly used way to account for the following kinds of losses in revenue metering:

1. Power Transformer Losses
2. Substation Losses
3. Transmission Line Losses

These techniques have a long revenue metering history and are widely used by electric utilities and generally accepted by regulatory bodies.

The EIG Loss Calculator and Nexus Meter implement this model but also allow for Utility Specific customization and extension of the basic Loss Model.

Extensions to include the effects of Transmission Line Capacitance and PF Correction Capacitors are in progress.
The EEI/IMO Loss Model is intended to account for losses that would have been metered if the meter was placed somewhere along the Transmission Line.

The Model may be extended to provide credits for off setting effects of PF Correction Capacitors or Transmission Line Capacitance but these are not part of the EEI/IMO Loss Model.
EEI/IMO Transformer Loss Model

The Simple High Side Transformer Model is used.

This model is the basic Loss Model used in Revenue Metering.

The primary source for this model is the "Handbook for Electricity Metering".

V, V², I², and V⁴ effects are compensated for real time in the Nexus meter.

However, if your business uses a different model, the Spreadsheet can be easily modified to use your model.

Assumptions:
1. No-load loss watts are proportional to V squared
2. Load loss watts are proportional to I squared
3. No-load loss VAr are proportional to V to the 4th power
4. Load loss VAr are proportional to I squared

See EEI Handbook for Electricity Metering Chapter 10 – Special Metering

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Transformer Loss Data

Information supplied by the transformer manufacturer includes:

- The kVA rating of the transformer bank
- Rated primary and secondary voltages
- No-load watts at rated voltage
- Load watts at rated current and at 75 C
- Percent exciting current at rated voltage
- Percent impedance at rated load.

The watt losses are given for both no-load and full-load, but the VAr losses have to be calculated.

Note: These values can be measured or values from similar transformers used if data is not available.
Transformer Loss Calculations

Loss Triangles can be used to compute Loss values not supplied by the Transformer manufacturer

- These relationships gives us a few simple formulas:

\[ FLV = \sqrt{FLVA^2 - FLW^2} \]

\[ NLV = \sqrt{NLVA^2 - NLW^2} \]

Related Terms:
- Load Losses = Copper (Cu) Losses
- No-Load Losses = Core or Iron (Fe) Losses

Values in Red not supplied by Transformer manufacturer
Transformer VAr Calculations

**No-Load VArs**

\[ NLVA = \%Ix \cdot \text{kVA Rated} \]

\[ NLV = \sqrt{NLVA^2 - NLW^2} \]

**Full-Load VArs**

\[ FLVA = \%Z \cdot \text{kVA Rated} \]

\[ FLV = \sqrt{FLVA^2 - FLW^2} \]
Transmission Line Losses

Transmission Line Losses are assumed to be is $I^2r$ Losses

Information Needed:

$r = \text{Resistance per unit of distance typically ohms/mile or ohms/km}$
$x = \text{Inductive reactance per unit of distance typically ohms/m or ohms/km}$
$LL = \text{Total length of line} = 3 \times \text{length of single conductor}$

So,

Transmission Line Current at primary-rated current of transformer is

$I_p = \frac{kVA \text{ Rated}}{(V_p \times \sqrt{3})}$ where $V_p = \text{Rated primary Voltage Line-Line}$

Transmission Line Losses can then be calculated as

Line Loss Watts (LLW) = $I_p^2 \times r \times LL$

Line Loss VArS (LLV) = $I_p^2 \times x \times LL$
Substation Conductor Losses

Substation Conductor Losses are also assumed to be $I^2r$ Losses

Information Needed:

$r$ = resistance per unit of distance typically ohms/foot or ohms/meter
$x$ = inductive reactance per unit of distance typically ohms/ft or ohms/m
$LC$ = Total length of conductor = $3 \bullet$ length of single conductor

The Secondary Current at Transformer Bank Rating is:

$Ir = \frac{kVA \text{ Rated}}{(3 \bullet Vr)}$  where $Vr = \text{ Rated Secondary Voltage Line-Neural}$

So Losses can be calculated as:

Conductor Loss Watts (CLW) = $Ir^2 \bullet r \bullet LC$
Conductor Loss VAr's (CLV) = $Ir^2 \bullet x \bullet LC$
Loss Relationships:

Empirically Derived Assumptions:
1. No-load loss watts are proportional to V squared
2. Load loss watts are proportional to I squared
3. No-load loss VArS are proportional to V to the 4th power
4. Load loss VArS are proportional to I squared

- These assumptions are used in the Meter to calculate Real-Time Loss Compensation
- They are also used in the Model as we adjust Power Transformer Loss Values to the Primary Side of the Instrument Transformers and to the Meter
Moving Losses

- Using the Loss Assumptions, High Side Losses can be moved to the Primary side of the Instrument transformers
## Total System Losses

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
<th>Watts</th>
<th>VAr</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Load Losses</td>
<td>Transformer Core</td>
<td>NLW</td>
<td>NLV</td>
</tr>
<tr>
<td>Load Losses</td>
<td>Transformer Windings</td>
<td>FLW</td>
<td>FLV</td>
</tr>
<tr>
<td></td>
<td>Transmission Line</td>
<td>LLW</td>
<td>LLV</td>
</tr>
<tr>
<td></td>
<td>Substation Conductors</td>
<td>CLW</td>
<td>CLV</td>
</tr>
<tr>
<td></td>
<td>Total Load Losses</td>
<td>TLW</td>
<td>TLV</td>
</tr>
</tbody>
</table>

Where:

- \( TLW = FLW + LLW + CLW \)
- \( TLV = FLV + LLV + CLV \)

**Summary of Losses Table**

**EIG Loss Calculator**

**Total System Losses** are Calculated by summing the Loss Components.

The Loss components are shown on the First Sheet of the EIG Loss Calculator.
Meter Loss Coefficients

Meter Loss Coefficients are used to adjust the meter for the effect of the Losses shown in the System Loss Table.

Losses are scaled by the meter rating to compute Meter Loss Coefficients.

\[ V_{Am} = 3 \cdot V_m \cdot TA \cdot CTR \cdot VTR \]  
(Meter VA Rating)

where, \( TA = \) Test Amps  \( CTR = \) CT Ratio  \( VTR = \) VT Ratio

These are the four Loss Coefficients programmed into the meter:

\[
\begin{align*}
\%LWFE &= \frac{LWFE}{V_{Am}} \quad (\% \text{ No-Load Loss Watts}) \\
\%LVFE &= \frac{LVFE}{V_{Am}} \quad (\% \text{ No-Load Loss VARs}) \\
\%LWCu &= \frac{LWCu}{V_{Am}} \quad (\% \text{ Full-Load Loss Watts}) \\
\%LVCu &= \frac{LVCu}{V_{Am}} \quad (\% \text{ Full-Load Loss VARs})
\end{align*}
\]

The Meter Loss Coefficients are used by the meter to compensate instantaneous calculations.
Dynamic Compensation

The Nexus Meter dynamically computes system losses instantaneously using the Meter Loss Coefficients and the assumed voltage and current relationships for Watts and VARs.

1. No-load loss watts are proportional to V squared
2. Load loss watts are proportional to I squared
3. No-load loss VArS are proportional to V to the 4th power
4. Load loss VArS are proportional to I squared

Demand, Energy, TOU, and Load Profile values are compensated instantaneously.
Extending the Loss Model

- Capacitance grouped or ungrouped can be added at the Transmission or Distribution Level of the model. They can be added to the table shown on Total System Losses slide but with a negative sign.
- Alternatively, any or all losses can be reduced by a fixed % by applying a Correction Factor to the Individual Loss Type or to Total Losses.